Analysis of Resilience in Virtual Networks

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Agenda

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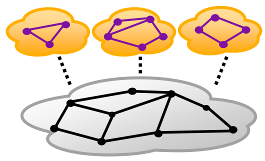
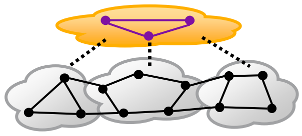
- Network virtualization model
- Failure types
- Comparison of resilience at different layers
  - Resource consumption
  - Service level resilience adaptability
  - Network setup and operation complexity
- Conclusion
- Q&A

Motivation

Resilience in Virtual Networks:



- Shared substrate resources
  - \+ Enhanced efficiency
  - – Increased effect of physical failures: many networks and services affected simultaneously



- Abstraction of the network
  - \+ Increased flexibility and overall view possibility
  - – More complex resilience design
- Different layers face different opportunities and challenges

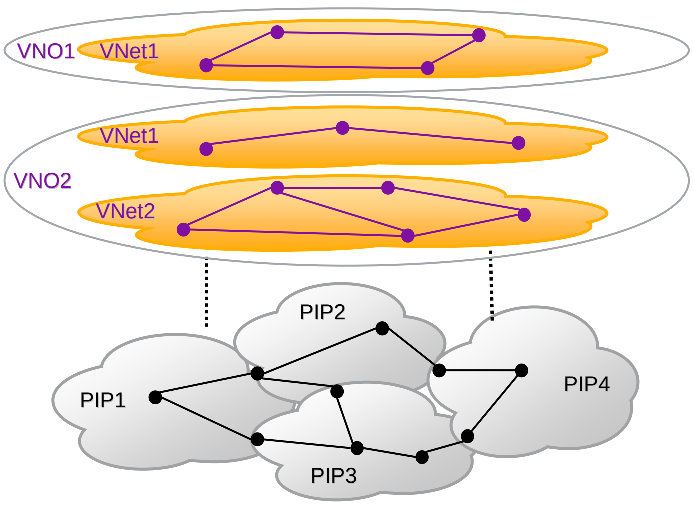
Comparative analysis → Optimal resilience design under different circumstances

Network virtualization model

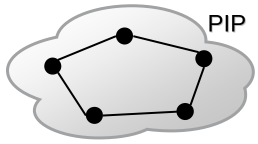
VNO: Virtual Network Operator

VNet: Virtual Network

PIP: Physical Infrastructure Provider



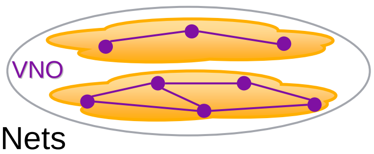
Network virtualization model (cont'd)



Physical Infrastructure Provider (PIP):

- Owns the physical infrastructure
- Monitoring of the physical and virtual resources
  - Physical Resources (PR): Total access and control
  - Virtual Resources (VR): Knowledge of the usage and physical location
- Network utilization optimization: optimal VR allocation for all virtual networks (VNets)
- Migration of VRs from one PR to another one
  - Overall optimization for all the VNets residing on the physical network
  - Shutting down a part of the network (e.g. energy efficiency, maintenance purposes)

Network virtualization model (cont'd)



Virtual Network Operator (VNO):

- Owns and operates one or several VNets
- VNet: virtual links and nodes
  - Requirements: node - CPU, memory, location, technology, …
link - bandwidth, delay, disjointness, …
  - Mapping to the network of one or more PIPs
- VNet request:
  - Advertisement of available virtual resources: PIPs → VNO
→ Overall view of the available resources!
  - Negotiation with various PIPs for establishing an optimal VNet
- Monitoring:
  - Buffer overflow, packet delay, …

Failure types

1) <u>Physical link/node failure</u>:

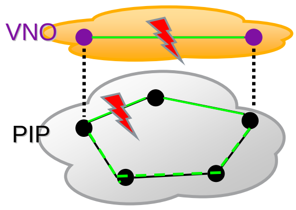
- Transport link failure
- Router/switch/server failure

PIP → First one to detect the failure!

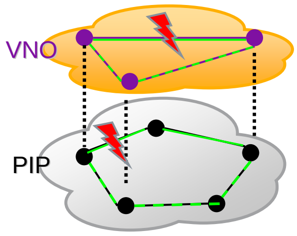
Resilience options:

1) Only PIP is responsible for resilience or VNO has no backup resource **PIP**
2) Only VNO reacts due to the contract **VNO**
3) Both can react **VNO** ✚ **PIP**
   - PIP: first one to detect the failure
   - Detected failure and recovery action taken signaled to VNO (also for Case2)
     - Failure escalation with triggering
     - Hold-off timer

PIP Resilience:



VNO Resilience:

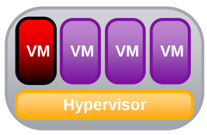


Failure types (cont'd)

2) <u>Virtual Machine (VM) failure</u>:

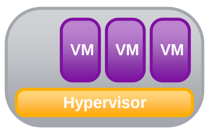
2.1) Internal failure **VNO**

- VNO → The owner and controller of the VMs
- PIP cannot (and shouldn't) react



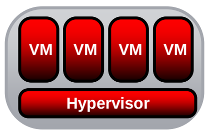
2.2) Complete failure **VNO** ✚ **PIP**

- No difference for VNO compared to physical failure



2.3) Hypervisor failure **PIP**

- VNO cannot do anything



3) <u>Control plane failure</u>:

- Topology Computation Engine
- Network Management System

} Data plane is still working
→ Need to be extremely fast not seen

Comparison of resilience at different layers

- Failure types and cases to be considered:
  - Where both VNO and PIP are able to react VNO ✚ PIP
  - Where fast reaction is required

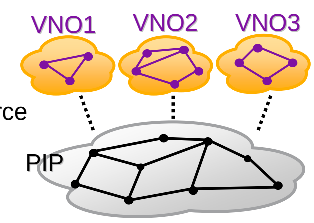
→ Physical node/link failures and complete VM failures

- Comparison metrics of having resilience at different layers:
  - Resource consumption
  - Service level resilience adaptability
  - Network setup and operation complexity

Comparison of resilience at different layers: Resource Consumption

<u>PIP</u>:

- Complete view of its network with…
  - its physical resources
    - Available virtual resources on a physical resource
    - Already leased resources and their properties
  - virtual resources residing on its network
    - Their location
    - Their properties

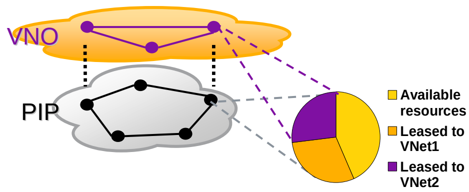


→Optimizing the resource utilization regarding all VNets in the network
  - Migration of resources if necessary
  - Backup resource pools and shared protection

Comparison of resilience at different layers: Resource Consumption (cont'd)

VNO:

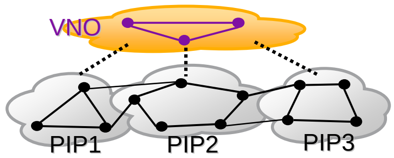
- Only limited view on the resources of a PIP
- No knowledge about the whole network structure of the PIP



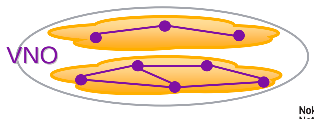
However…

- Overall view over the available resources of all the PIPs

→Optimal combination of available resources from several PIPs for both primary and backup resources



→Sharing of the backup resources at the VNO level



Comparison of resilience at different layers: Service level resilience adaptability

PIP:

Limited: Should not influence service handling

→No optimization of resilience mechanisms possible depending on the actual services

VNO:

Comprehensive knowledge about the services and traffic characteristics in its VNets

→Optimization of the choice of backup resources and recovery actions accordingly

→Adaptation of the resilience level depending on the running services

Comparison of resilience at different layers: Network setup and operation complexity

<u>PIP</u>:

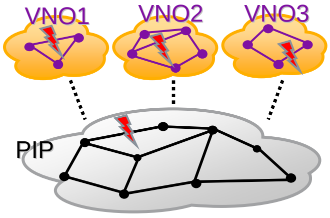
- Close to the origin for the considered failures

→More knowledge about the failure

→Fast reaction ability

- Multiple VNets share the same physical resource

→If the problem is fixed at the PIP layer, it is solved for all the affected VNets



Comparison of resilience at different layers: Network setup and operation complexity (cont'd)

<u>VNO</u>:

- No direct knowledge about the physical failures

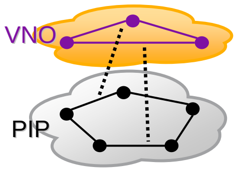
→Need for signaling and coordination

- Due to one physical failure many VNets might be affected

→Need for separate reaction by each VNO

- Virtual resources for services should obey physical disjointness

→Need for disjointness information request



Conclusion

- Resource consumption
  - PIP: Complete knowledge of its network
    Optimization over all residing VNets
  - VNO: Overall view of the available resources of all PIPs
- Service level resilience adaptability
  - VNO: Optimization regarding the services
- Network setup and operation complexity
  - PIP: Simplicity regarding signaling and scalability

- Future work
  - Quantitative analysis of the results: Delay, resource consumption, cost, complexity
  - Design of appropriate resilience mechanisms

Q&A

Thank you for your attention!

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